Cycle Review

→ Over the past several weeks we've discussed cycles for power generation and providing heating or cooling. The basics behind the solution ~~of~~ to any of these cycles:

1) Look @ the ~~resource~~ or temperatures of the reservoirs that the system is operating between, from this you can calculate the maximum efficiency or performance of the cycle relative to carnot.

2) Draw a table & fix the states of the cycle, then plot the states & processes to make sure they make sense.

3) Analyze the components of the system.

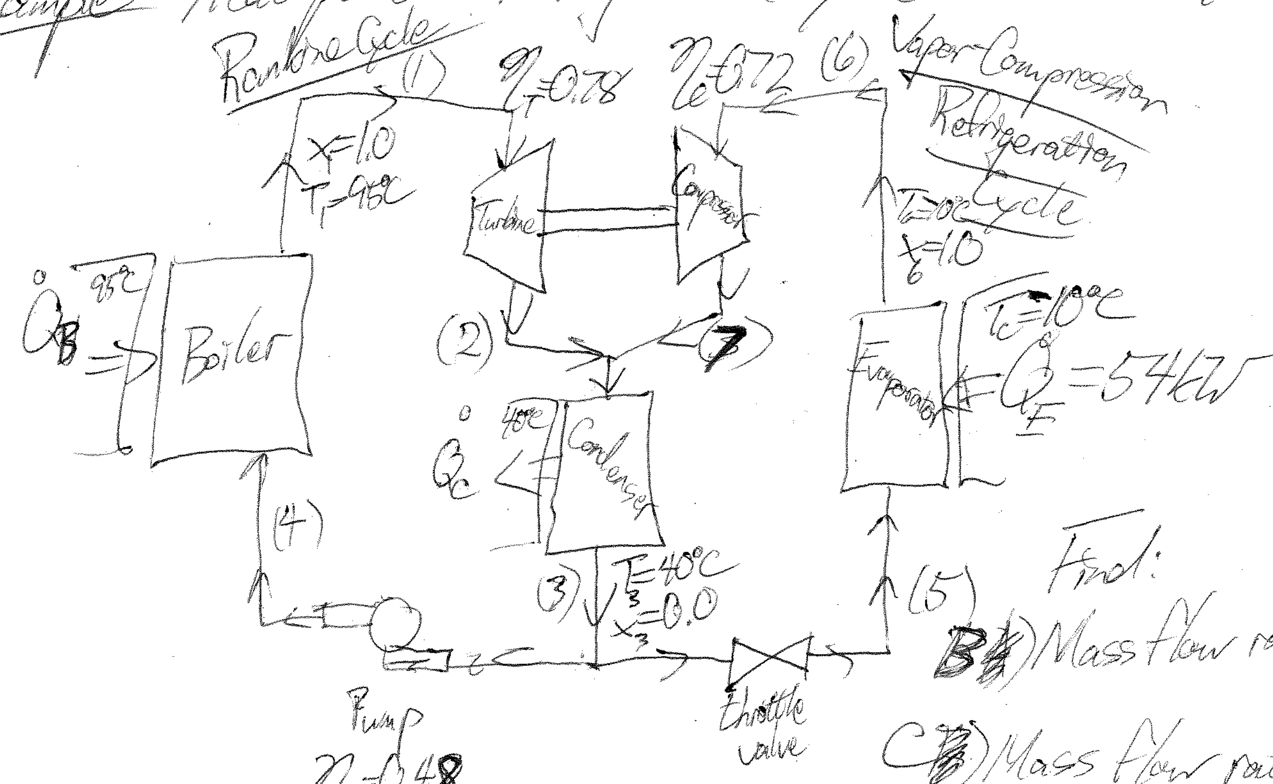
4) Compare ideal system performance (#1) with actual system performance found in #3.

→ If you can accomplish these, you've ~~mastered~~ got ME301 down.

→ Basically the only thing holding you back is the size & # of components some of these cycles can have.

ME301 Sp2011 33.2

Example: Heat powered refrigeration cycle with R134a:



Find:

B) Mass flow rate through evaporator.

C) Mass flow rate through boiler

D) Actual COP for cycle

A) Max possible COP for cycle

Max COP for cycle ... is this a heat engine or a fridge? well both

$$COP_{Max} = COP_R \, \eta_{Engine} \qquad COP_R = \frac{T_C}{T_H - T_C} = \frac{283K}{313K - 283K}$$

$$COP_R = 5.26$$

$$\eta_{Engine} = 1 - \frac{T_C}{T_H} = 1 - \frac{313}{368} \Rightarrow \eta_{Engine} = 0.15$$

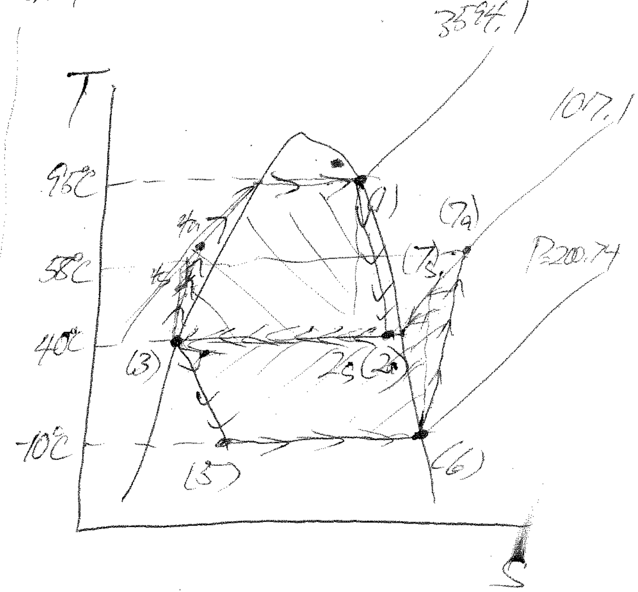
$$COP_{Max} = 0.789$$ wow Low

Let's see what we can actually get

ME301 Sp2011 3.3

State	T (°C)	P (kPa)	x (-)	h (kJ/kg)	s (kJ/kg-K)
1	$\boxed{95^\circ C}$	3594.1	$\boxed{1.0}$	272.26	0.85289
Turbine					
2		$=P_3$		256.22	
Condenser					
3	$\boxed{40^\circ C}$	1017.1	$\boxed{0.0}$	108.26	0.39486
Pump					
4		$=P_1$		[redacted]	
Throttle					
5	$-10^\circ C$	$=P_6$	0.3384	$=h_3$	0.42
Evaporator					
6	$\boxed{-10^\circ C}$	200.74	$\boxed{1.0}$	244.51	0.93766
Compressor					
7		$=P_2$		291.02	

Table A-11



State 5 $x = \dfrac{h - h_f}{h_g - h_f} = \dfrac{\overset{108.26}{\cancel{244.51}} - 38.55}{244.51 - 38.55} = x_5 = .3384 = \dfrac{s_5 - s_f}{s_g - s_f}$

69.71

205.96

Got $\Rightarrow s_5 = 0.3384(0.93766 - 0.15504) + 0.15504 \Rightarrow s_5 = 0.42$

$\eta_T = 0.78 = \dfrac{h_1 - h_2}{h_1 - h_{2s}} = \dfrac{272.26 - h_2}{272.26 - h_{2s}}$

Can do ↓

$\rightarrow$ 1017.1 kPa $s_1 = s_{2s}$

$\dfrac{h_{2s} - 108.26}{271.27 - 108.26} = \dfrac{\overset{.45803}{0.85289 - 0.39486}}{\underset{.5205}{0.91536 - 0.39486}}$

$\Rightarrow h_{2s} = 251.7$

$\rightarrow h_2 = 256.223$

$\eta_C = 0.72 = \dfrac{h_{7s} - h_6}{h_7 - h_6} =$

Can do, got

1017.1 kPa $s_6 = s_{7s}$

$\cancel{\dfrac{h_{7s} - 108.26}{271.27 - 108.26}}$

$\dfrac{\overset{.0196}{.93766 - .9179}}{\underset{.0346}{.9525 - .9179}} = \dfrac{h_{7s} - 271.71}{282.74 - 271.71}$

0.87998

s_{7s} s_{low} s_{high} s_{low}

0.571

$h_{7s} = 278$

$\rightarrow h_7 = 291.02$

33.4 ME301Sp2014

$S_5 = S_{4S} = 0.\cancel{3}\,\overset{39486}{}$ ← less than S_f @ 95°C so in ~~saturated~~ Compressed liquid region! no tables!!

$$\eta_p = 0.48 = \frac{h_{4S} - h_3}{h_4 - h_3}$$

~~→ in this case we'll estimate h_{4S} where $S_{4S} = S_f$~~

~~$h_4 = \frac{h_3}{\ldots}$ 108.26 $h_4 = 125.54$ → this is tough without a real~~ fluid model → this cant be done

→ Purpose is to find the work required by pump is there another way?

$$\dot{W}_p = \frac{\dot{m} v_3 (P_4 - P_3)}{\eta_p}$$ → we need $\dot{m}$

We've got enough, lets analyze components

For Evaporator: $\dot{E}_{in} = \dot{E}_{out} + \frac{dE_{cv}}{dt}^{0} \Rightarrow \dot{Q}_{in} + \dot{m}(h_5) = \dot{m}(h_6)$

$$\frac{\dot{Q}_{evap}}{(h_6 - h_5)} = \dot{m}_{evap} = \frac{54\,kW}{244.51 - 108.26} \Rightarrow \dot{m}_{evap} = 0.396\,kg/s$$

Whats next $\dot{W}_C = \dot{W}_T$ → $\dot{W}_C = \dot{m}(h_7 - h_6) \Rightarrow 0.396(291.02 - 244.51)$

$$\dot{W}_C = 18.42\,kW$$

→ $\dot{W}_T = \dot{m}_{Rankine}(h_1 - h_2) \Rightarrow \dot{m}_{Rankine} = \frac{18.42\,kW}{(272.26 - 256.2)} \Rightarrow \dot{m}_{Rankine} = 1.1\,kg/s$

$$\dot{W}_p = \frac{1.1(\overset{.0009592}{0.0008720})(3594100 - 1017100)}{0.48} = \dot{W}_p = 5749.7\,W = \dot{m}(h_4 - h_3) = h_4 = 113.04\,kJ/kg$$

$$\dot{Q}_B = \overset{\dot{m}_{Rankine}}{1.1}(h_1 - h_4) = 1.1(272.26 - 113.04) \Rightarrow \dot{Q}_B = 175.1\,kW$$

$$COP_{actual} = \frac{\text{Want}}{\text{Payed}} = \frac{\dot{Q}_{evap}}{\dot{Q}_{cond}} = \frac{54\,kW}{175.1\,kW} = \underline{COP_{actual} = 0.308}$$ lower than Max